Hawkes processes for market order arrivals on the German intraday power market and their application in optimal market maker pricing

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We consider a market maker (MM) operating on the intraday market for power deliveries in Germany.

We study the problem of how she can optimally price her buy and sell limit orders (LO).

Dependence on her current inventory as well as market characteristics and state, e.g.

- Self-excitement in market order (MO) arrivals, ...
- Bid-ask spreads well above tick size
Value function

We consider the following value function for the MM:

\[
V(t, X, q, S, H, \lambda) = \sup_{(\delta_{SL}(u), \delta_{BL}(u))_{t \leq u \leq T} \in \mathcal{A}} E \left[ X(T) + q(T) \left( S(T) - \text{sign}(q(T))H(T) - \alpha q(T) \right) - \phi \int_t^T q(u)^2 du \right] | F(t),
\]

where

\[
\text{sign}(q(t)) := \begin{cases} 
1 & \text{if } q(t) > 0 \\
0 & \text{if } q(t) = 0 \\
-1 & \text{if } q(t) < 0.
\end{cases}
\]

and \( \mathcal{A} \) is the set of admissible controls.
Different $\phi, \alpha$

(a) $\alpha = 0$.

(b) $\phi = 0$.

Figure: Optimal markup over time for different running and terminal inventory penalties. $q = 0$ MWh, $h = 0.5$ EUR per MWh.
Different $q, \phi$

Figure: Optimal markup over time for different inventory levels and inventory penalties. $h = 0.5$ EUR per MWh.
Different $h$

(a) $\delta_{SL}^*$.  

(b) $h + \delta_{SL}^*$.  

Figure: Optimal markup and half spread plus optimal markup over time for different half spreads. $q = 0$ MWh, $\phi = \alpha = 0.1$.  

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Figure: Blue: average number of sell MOs (first row), buy LOs placed into the bid-ask spread (second row) and buy LOs canceled from the first level of the order book (third row) in bins of 5 seconds over 5 minutes after the arrival of a sell MO (first column), a buy LO being placed into the bid-ask spread (second column) and a buy LO being canceled from the first level of the order book (third column).
Test design

- Contracts with delivery in peak hours of 05/2015 and 06/2015 are considered.
- 2 hours of trading ending 5 mins before gate closure.
- Point process param. are estimated for each peak hour with data from 04/2015 and averaged b/w buy/sell side.
- Expected impacts are estimated for all peak hours with data from 04/2015 and averaged b/w buy/sell side.
- Fill probability param. are estimated for all peak hours with data from 04/2015 and averaged b/w buy/sell side.
- One unit of inventory is 0.1 MW.
- We assume that if the worst price executed by a MO is the same or worse than the price of the MM’s LO on the relevant market side, the MM’s LO is executed.
Result example

(a) PnL.  
(b) Inventory.  
(c) Volume.

Figure: Distributions resulting from backtesting the strategy. $\phi = 1, \alpha = 0.$
### Table: Mean of PnL, inventory and traded volume at the end of trading.

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<thead>
<tr>
<th></th>
<th>PnL (EUR)</th>
<th>Inventory (MWh)</th>
<th>Volume (MWh)</th>
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(a) Naive.

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(b) NHPP.

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(c) Hawkes.
Performance indicators

(a) PnL.  
(b) Sharpe ratio.  
(c) PnL per traded volume.

Figure: Performance indicators as a function of $\phi$ for model with excitement (blue) and without (red). $\alpha = 0$. 

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▶ $\phi$ has a substantial impact on markups/downs.
▶ Optimal markups/downs vary substantially with current half spread.
▶ Excitement may be observed empirically in events which (potentially) have an impact on mid price and half spread.
▶ Backtest: Mean PnL is positive. Including Hawkes increases mean PnL and decreases mean traded volume.